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Research Article

A Grey-BPNN Model for Evaluating the Competitiveness of Chinese Contractors in the High-Speed Rail Market in Europe

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With the planning and progress of the construction of the trans-Eurasian high-speed rail (HSR) network, it becomes an important issue for Chinese contractors to enter the European HSR market. Facing the world's most competitive contractors and their high technology levels, Chinese contractors will need to know their advantages and disadvantages, so as to make necessary improvements. In this study, contractors for HSR are divided into two groups: construction contractors and rail equipment suppliers. In order to evaluate the competitiveness of HSR contractors, a Grey-BPNN model that combines the grey relational analysis and backpropagation neural network (BPNN) is proposed. The Grey-BPNN model is expected to analyze the overall competitiveness of Chinese contractors in the European HSR market and provide informative decision support for them. The study results show the following: (1) in the field of HSR construction, the competitiveness gap between the top-tier Chinese contractors and the most competitive international contractors is small. Chinese contractors' competitive advantages lie in medium- and low-technology-level projects, with a strong development potential. However, they highly depend on Chinese domestic market and lack in intangible resources, like management ability and market development ability; (2) for rail equipment suppliers, China Railway Rolling Stock Corporation (CRRC) ranks among the top-tier leaders of the international market. CRRC's greatest competitor in the European HSR market is Siemens, and CRRC is much more competitive than others in the sustainable development capability. However, CRRC needs to increase the quantity of patents and Research and Development (R&D) expenditures in transportation. As a weak transportation patent holder, CRRC has a potential risk of getting intellectual property litigations in the European HSR market.

1. Introduction

In 2013, Chinese President Xi Jinping proposed the "Belt and Road Initiative" to promote infrastructure construction and connectivity among countries in Europe, Asia, and Africa to form regional cooperation platforms. The operating mileage of China's high-speed rail (HSR) has reached 14,620 kilometers, which is the longest operating mileage of HSR and the largest scale of construction in the world [1]. China's HSR has become "national business card". It is one of the most successful strategic industries established by the use of institutional and innovative advantages since China's reform and opening up.

In August 2017, the Russian Railway Company proposed a Eurasian high-speed trunk project, a total cost of nearly $130 billion, and the project was expected to start in 2018 and complete in 2026. In addition to the huge engineering demand on the Eurasian HSR, European countries also have plans and willingness to build HSR. For example, the United Kingdom is expected to invest in the HS2 project of 51 billion, and the eight European countries are planning to invest 200 billion in the construction of 9000 km of high railway lines, including the French HSR project, the Polish HSR project, and the Swedish HSR line [2]. The European HSR network is the only one in the world to provide transnational services, and the purpose of construction is mainly to connect the capitals of various countries [3]. Therefore, the construction of Eurasian HSR and the development of European HSR market not only have important strategic significance, but also will bring broad development space for Chinese contractors. When Chinese contractors desire to explore the market of the HSR in Europe, they have to face fierce competition. Hence, it is necessary to further investigate the competitiveness of Chinese contractors compared with the world's top-tier HSR contractors.

Traditional research on competitiveness evaluation discovers the advantages and disadvantages of enterprises themselves and directly guides enterprises to formulate market competition strategies. However, enterprise competitiveness evaluation is a complicated and nonlinear task which involves many factors [4]. Therefore, further exploration of the appropriate evaluation method to survey and analyze these influential factors is needed. Competitiveness evaluation methods can be divided into subjective evaluation and objective information evaluation. Subjective evaluation methods are often conducted by means of questionnaires and expert interviews [5] and evaluated by various research methods, such as analytic hierarchy process [6], fuzzy comprehensive evaluation [7], and factor analysis [8]. Subjective evaluation methods can reflect the specific strategic information of different enterprises, but they come with some problems like subjective bias and expert bias. Contrarily, objective information evaluation methods are often based on publicly available secondary data [5], including grey relational analysis [9], backpropagation neural network (BPNN) [10, 11], and data envelopment analysis (DEA) [12]. Objective information evaluation methods can overcome the shortcomings of subjective evaluation methods, but it is necessary to consider premise assumptions and use conditions of different models in the process of evaluation.

Generally speaking, civil construction and rail equipment account for 50% and 15% of the total HSR cost, respectively [13]. Thus, this study is focused on civil construction contractors and equipment suppliers. Owing to the limited number of global rail equipment suppliers, data are hard to come by and information ambiguity is relatively high. As the competitiveness evaluation methods used in this study should be able to effectively deal with complex problems with a small sample size and information of nonlinear and imprecise nature, it is necessary to thoroughly explore proper competitiveness evaluation methods for HSR contractors and combine them with innovative approaches if possible.

Most of the prior studies used the competitiveness index model [14], the modified diamond model [15], analytic hierarchy process (AHP) [16], or adopted the exploratory factor [17] to analyze the competitive advantages of the HSR contractor. Few studies, however, have investigated construction contractors and rail equipment suppliers and used the Grey-BPNN model to analyze the overall competitiveness of contractors in the European HSR market. In this regard, this study serves to bridge the gap and contributes significant theoretical and practical insights into competitiveness evaluation in the HSR context. These results would provide informative decision support for Chinese construction contractors and rail equipment suppliers.

Based on the above research questions, the authors coupled theories with experimental analysis to resolve the problems. The main objectives of this study are as follows: (1) to evaluate the competitiveness of Chinese HSR construction contractors in exploring European HSR market based on BPNN; (2) to construct the Grey-BPNN model based on the grey relational analysis and BPNN, for evaluating the competitiveness of rail equipment suppliers in exploring the European HSR market; and (3) to provide decision and competitive strategy support for Chinese HSR contractors in exploring the European HSR market.

The structure of the paper comprises introduction, literature review, competitiveness evaluation for HSR construction contractors, competitiveness evaluation for rail equipment suppliers, and conclusions.

2. Literature Review

2.1. Competitiveness Theories. The research of competitiveness can be divided into three levels: national competitiveness, industrial competitiveness, and enterprise competitiveness. National competitiveness refers to the ability of a country to create, produce, and market products or services in international trade and to add value to the resources originally invested [18]. Industrial competitiveness refers to the ability of an industry to maintain a stable level of high profits and a high employment rate in an internationally competitive environment [19]. Enterprise competitiveness refers to the ability of an enterprise to provide a more attractive price and quality than its domestic and foreign competitors in the design, production, and sale of products or services [20]. The research object of this study is the HSR contractor, so it focuses on the level of enterprise competitiveness.

Many scholars have studied the competitiveness of enterprises and analyzed it from different angles, forming the main framework of competitiveness theory together, but there is no unified conclusion at present. The three most dominant schools of enterprise competitiveness are the competence theory, the resource theory, and the market structure theory. The results of classic enterprise competitiveness studies are mainly to establish a theoretical analysis framework, and no quantitative research has been conducted. Prahalad and Hamel [21] believe that the core competence of an enterprise is the unique ability and technology to deliver special benefits to customers. The core competence of enterprises can be judged by the ability of entering the market, improving the efficiency of enterprises and being difficult to imitate. Enterprise capability theory includes core competence theory, basic competence theory, dynamic capability theory, and process-based capability theory. Wernerfelt [22] proposed the meaning of internal resources for the company to maintain competitive advantage and incorporated company capability into the scope of company resources, arguing that resources are the sum of the capabilities and assets owned by the company. According to the view of enterprise resource, the competitive advantage of enterprise comes from the differences of tangible resources, intangible resources, and accumulated knowledge among enterprises. These resources are of value, scarcity, knowledge, and nonreplicability, and the competitiveness of enterprise is highly related to these resources. Porter [23] proposed the diamond model for analyzing the competitiveness of the industry, the five-force model, and value chain model for analyzing the competitiveness of enterprises. The five-force model mainly discusses the influence of suppliers, buyers, potential entrants, substitutes, and competitors on the competitive advantage of enterprises in the external competitive environment. Porter value chain is to discuss the competitiveness brought by the internal operation of enterprises from the two aspects of enterprise basic activities and supporting activities, and the internal activities can also be classified into the scope of enterprise capability and enterprise resources. It can be seen that the study of enterprise competitiveness by Porter overlaps with the competence theory and resource theory.

In the empirical research of enterprise competitiveness, many scholars choose competitiveness components from different angles. Schilke [24] studied the competitiveness of enterprises overseas from the two dimensions of strategic performance and financial performance. Wu and Parkvithee [25] used content analysis to study the influence of macroenvironment factors and internal factors on the competitiveness of enterprises. Fleaca et al. [26] focuses on the internal factors and processes of the enterprise by using the functional analysis technique to study the competitiveness of the enterprise. For the contractor, Zhou [27] discusses the relationship between sustainable management and contractor competitiveness and holds that contractor competitiveness mainly includes enterprise information ability, enterprise strategy ability, and enterprise wealth ability. Xie [28] proposed that the competitiveness of contractors should be considered at both the enterprise and project levels, including core technical capabilities, human resource capabilities, market development capabilities, organizational and management capabilities, and project management and implementation capabilities. Huang et al. [29] analyzed the components of contractor's competitiveness through comparative study of domestic and foreign hydropower contractors and concluded that contractor's competitiveness includes strategy, organization, market, culture, innovation, and environmental adaptation. Badawy [30] introduces the evaluation system of competitiveness from three new pillars: (1) nonfinancial internal pillar; (2) nonfinancial external pillar; and (3) financial pillar, which can help construction companies manage short-term and long-term strategic plans and goals. Some scholars regard the relationship between organizations as the resource or capability of the enterprise, such as the relationship between the contractor and the subcontractor [31] and the contractor network [32], to explore its influence on the competitiveness of contractor. It can be seen that the components selected in the evaluation of enterprise competitiveness are different and should be fully combined with the characteristics of the industry.

Throughout the study of the components of competitiveness, it is inseparable from the three lines of mainstream theory: enterprise capacity, enterprise resources, and the adaptability of the competitive environment. Since there are many overlaps among competence theory, resource theory, and market structure theory and the HSR market is not a fully open and competitive market, this paper evaluates the competitiveness of HSR contractor from the aspects of enterprise capability and enterprise resource.

2.2. Backpropagation Neural Network (BPNN). Backpropagation neural network (BPNN) is the most widely used research method in artificial neural network. It uses electronic circuit or computer program to simulate the information processing structure of neural protruding connection and learns the regulation of samples by the backpropagation algorithm, which belongs to a mathematical model. Its main characteristic is that the implicit layer can be used to solve nonlinear problems. A hidden layer is established to fit the characteristics of our sample data and prevent the over fit phenomenon. The number of neurons in the input layer corresponds to the number of evaluation index, while the number of neurons in the output layer corresponds to the evaluation target for this article, namely, the competitiveness indices.

Goh [33] discusses the application of BPNN to the modeling process of complex systems. Goh points out that in complex engineering systems, there are usually not very complete and accurate data. In this case, the application of BPNN can obtain good prediction and evaluation results. The application of BPNN has been more common in the research, but the use of BPNN to explore the competitiveness of enterprises is still rare. BPNN are often used in performance evaluation [34], pattern recognition [35], and simulation [36]. Zhiyuan et al. [37] studied the enterprise competitiveness evaluation based on the wavelet neural network forecasting system. It combined the theory of wavelet neural network, database of company annual report, and evaluation of enterprise competitiveness. In the field of construction management, Zhang et al. [38] applied the neural network to the bidding process of the project, decomposing the contractor's comprehensive capability into credit performance, human resources, equipment management, quality management, and safety and civilization management, etc.; on the basis of fuzzy processing of indicators, the evaluation model of BPNN for contractor is established. Qiao [39] combined BPNN with AHP and applied the neural network to the bidding process and set up the index system of the factors influencing the bidding price and finally constructed the neural network model to predict the bidding price. Zhang and Wang [40] applied the BPNN to the selection decision of the project contractor and determined the five evaluation indices by Delphi, such as project quotation, project duration, project quality, construction technology, and enterprise reputation.

Although the BPNN is applied in the field of construction management, it is more used to build the selection model of contractors, not directly used to evaluate competitiveness. The BPNN has high nonlinear mapping ability, which is suitable for dealing with problems involving many factors, conditions, and imprecise information. It has strong superiority in evaluating and forecasting competitiveness. However, The BPNN is generally suitable for large sample data analysis, and there may be insufficient training accuracy for small sample data. Therefore, in the application of the BPNN, it is necessary to optimize and improve the model according to the characteristics of the samples.

2.3. Grey Relational Analysis. Grey relational analysis, which was proposed by Deng [41], is an important part of grey theory. The basic principle of grey relational analysis is to judge the degree of correlation between indicators by the similarity of geometric shapes of different index curves. It has remarkable effect in dealing with small samples, poor information, and data with no significant statistical distribution regulation. Its main defect is that the grey relational analysis is based on the similarity analysis of the changing trend of the sequence. It has insufficient ability to mine some hidden rules, and the result of association order is not robust.

Due to the complexity, ambiguity, and high degree of uncertainty of the project [42], in the field of construction management, many scholars have also adopted grey relational analysis as a research method. Zhang [43] established a green evaluation index system from four aspects: qualification, technology, economy, and management. The multilevel grey relational analysis was used to evaluate the bidding, and the applicability of the grey relational analysis was confirmed by case studies. Zhang [44] optimized the grey relational degree theory and proposed a multiobjective decision-making model which provided decision support for the selection of highway engineering general contracting projects. Yu and Duan [45] used grey relational analysis to screen the evaluation index of investment risk of engineering project and carried out risk evaluation with fuzzy evaluation model. Wei et al. [46] studied the prequalification method of contractor combined with interval number and grey relational analysis to provide decision support for uncertain information and subjective preference. Rajesh and Ravi [47] combined with grey relational analysis and sensitivity analysis to study the supply side selection of elastic supply chain. Jato-Espino et al. [48] summarize the multi-index decision methods used in the construction industry and consider that the grey relational analysis is often used in project decision-making. Zavadskas et al. [49] establish an index system of project manager selection through literature review and use the multiple decision-making methods of complex proportional assessment (COPRAS) and grey relational analysis to select the project manager.

The grey relational degree can measure the interrelation and influence between different sample sequences and can reflect the difference between the sequence and the optimal reference sequence. The higher the order of grey relational degree, the better the result, which can be used for the comparison and evaluation of competitiveness. By collating the relevant literature, it can be seen that most of the research is focused on project selection decisions and risk assessment, and the contractor's competitiveness evaluation is rarely involved. Considering the sample characteristics of HSR contractors, this study innovatively combines grey relational analysis with the BPNN to optimize and improve the model and constructs Grey-BPNN model for fuzzy evaluation.

3. Methodology of BPNN for Competitiveness Evaluation of HSR Construction Contractors

In this study, the BPNN is used to construct the competitiveness evaluation model of HSR construction contractors, as shown in Figure 1. Firstly, the evaluation index system is constructed by AHP and literature review, and the data of Engineering News-Record (ENR) 2015-2016 is selected to train the BPNN. Secondly, the competitiveness of ENR 2016-2017 HSR construction contractor is evaluated by using the trained the BPNN. Finally, the competitiveness of Chinese, international, and European contractors is compared and analyzed.

3.1. Competitiveness Evaluation Index System for HSR Construction Contractors. Competitiveness evaluation is based on three basic perspectives: resource theory, capability theory, and market structure theory. Since the competitiveness of HSR construction contractors mainly refers to the ability to contract projects and obtain more turnover, this paper aims to establish a competitive evaluation system for HSR construction contractors based on the resource theory and capability theory. Inductive statistics of competitiveness evaluation indices were collected from the literature and are summarized in Table 1.

It can be seen that the cumulative frequency of market capability, tangible resources, intangible resources, operation ability, and internationalization ability is 64%, which is the main influencing factor. Financial capability and management ability are secondary influencing factors, and the rest are general influencing factors. Since this study examines the competitiveness of construction contractors in the HSR market, the market capacity is classified as the market development ability and the transportation niche market ability. Therefore, the competitiveness evaluation indices system of HSR construction contractors mainly includes two aspects: enterprise ability and enterprise resource; enterprise ability includes four aspects: internationalization ability, market development ability, transportation niche market ability, and operation ability; enterprise resources include tangible resources and intangible resources.

Considering the availability, validity, simplicity, and comparability of the data, this paper takes the ENR as the data source of the secondary indicators. The study uses X_1–X_{11} to represent the secondary indicators that are used as the source of the elements of competitiveness identified earlier in this paper. Internationalization ability refers to the ability of contractors to explore overseas markets. The ENR

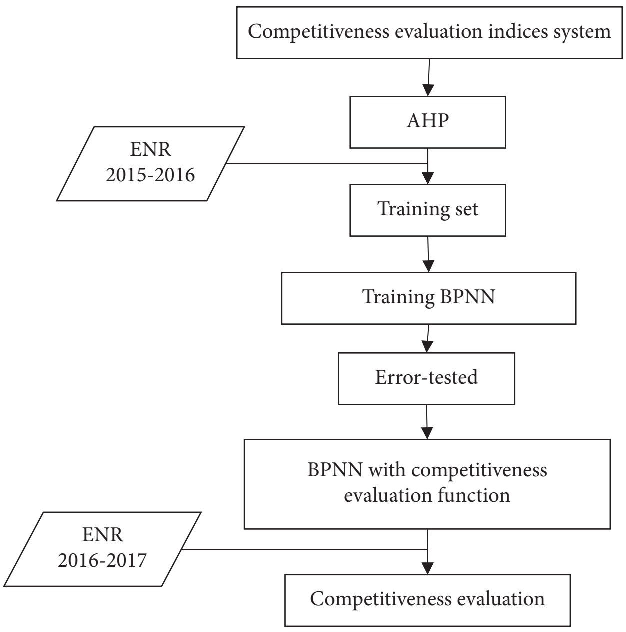

Figure 1: Competitiveness evaluation model of HSR construction contractor.

Table 1: Statistical results of competitiveness evaluation indices.

Indices	Frequency	Rate	Cumulative frequency
Market capacity	23	0.19	0.19
Tangible resources	19	0.16	0.35
Intangible resources	13	0.11	0.45
Operation ability	12	0.10	0.55
Internationalization ability	10	0.08	0.64
Financial capacity	9	0.07	0.71
Management ability	9	0.07	0.79
Innovation ability	8	0.07	0.85
Profitability	6	0.05	0.90
Technical capability	5	0.04	0.94
R&D	2	0.02	0.96
Quality management capability	2	0.02	0.98
Negotiating ability	1	0.01	0.98
Safety management capability	1	0.01	0.99
Solvency	1	0.01	1.00

includes the international sales (X_1), which directly reflects the contractor's degree of international ability. The international revenue growth (X_2) can reflect the dynamic change of international ability through the data of ENR for two years. Taking the international sales and international revenue growth as the constituent elements of the international ability, the contractor's international ability can be more objectively measured from both static and dynamic aspects. Similarly, the market expanding ability is the ability of a contractor to obtain a new contract or new order, which is indicated by the new contracts (X_3) and new contract growth (X_4). The transportation market ability refers to the contractor's ability to explore the market for traffic construction and is indicated by the international transport market sales (X_5), transportation market growth (X_6), and proportion of traffic projects (X_7). Using the proportion of traffic projects (X_7) to reflect the contractor's attention to the traffic construction market, it can more comprehensively consider the contractor's traffic construction market ability; the operation ability reflects the contractor's ability to operate sustainably and is indicated by the total revenue growth (X_9). Tangible resources refer to the financial and physical resources of the contractor, which will eventually be converted into the turnover and profits of the enterprise. Tangible resources is indicated by the total revenue (X_8). Intangible resources refer to factors that are not lost in the process of producing value. Intangible resources is indicated by the brand value (X_{10}) and local contractor (X_{11}). Therefore, the evaluation system of HSR construction contractors' competitiveness is as shown in Figure 2.

3.2. Weights of Competitiveness Evaluation Indices. Because competitiveness analysis is essentially a multiobjective decision-making problem, AHP can be used to determine the indices weight. AHP is to decompose complex problems into several factors hierarchically and compare the importance of the factors in order to get the weight of each factor [50]. In this study, 15 senior executives of international contractors were asked to rate the indicators of competitiveness, construct the judgment matrix according to the final comprehensive average score, and test the consistency of the judgment matrix. The application of AHP includes four steps. First, analyzing the problem from a different level and building a hierarchical structure model. Then, the judgment matrix of each level should be constructed according to the decision maker's score. The third step is to test and judge the consistency of proof; after the consistency test, the final weight of each layer element for the total goal is finally calculated [51]. Judgment matrix in this study passed the consistency check. The weight of the primary index and the secondary indices and the synthesis weights multiplied by the two weights are shown in Table 2.

3.3. Sample Selection and Data Preprocessing. In order to assess the contractor's competitiveness, the contractor's detailed and accurate information is required. This study obtains the company information of the contractors from American McGraw hill ENR report and selects the 2015 ENR 250 and 2016 ENR 250 annual reports [52, 53] as the training data set of the BPNN. 2016 ENR 250 and 2017 ENR 250 [53, 54] are selected as the forecast and evaluation set to verify the applicability of the BPNN in competitiveness evaluation. Because the research object is the HSR construction contractors, it focuses on the transportation contractor, that is, the contractor involved in the traffic business in ENR. After detailed screening and statistics, 123 transportation contractors are selected as the training set, which were numbered from 1 to 123, respectively, according to the ENR ranking in 2015-2016. And, 133 transportation contractors are selected as the forecast and evaluation set in ENR 2016-2017.

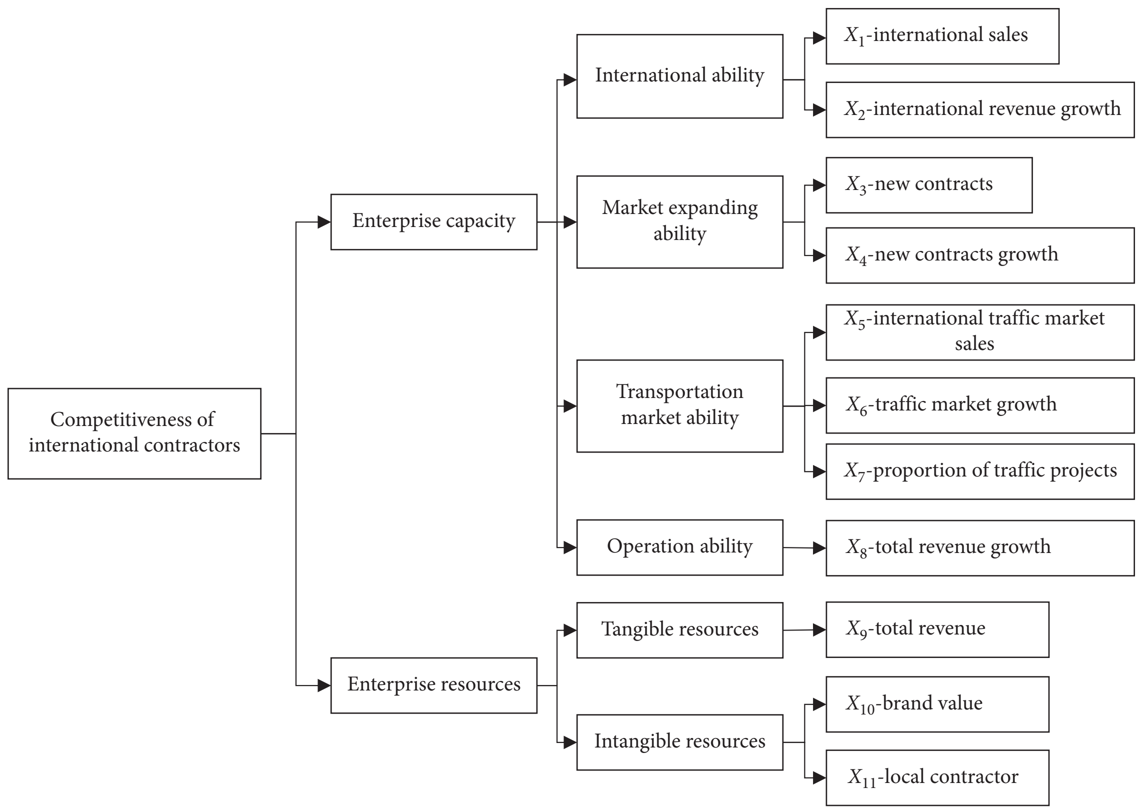

Figure 2: Evaluation system of HSR construction contractors' competitiveness.

Table 2: Weight of evaluation indices.

Competitiveness indices	First-grade indices	Weight of first-grade indices	Second-grade indices	Element of secondary indices	Weight of second indices	Synthetical weight
Competitiveness of contractors	Enterprise capacity	0.62	International ability	X_1-international sales	0.27	0.17
				X_2-international revenue growth	0.13	0.08
			Market expanding ability	X_3-new contracts	0.06	0.04
				X_4-new contracts growth	0.06	0.04
			Transportation market ability	X_5-international traffic market sales	0.27	0.17
				X_6-traffic market growth	0.06	0.04
				X_7-proportion of traffic projects	0.08	0.05
			Operation ability	X_8-total revenue growth	0.07	0.04
	Enterprise resources	0.38	Tangible resources	X_9-total revenue	0.38	0.15
			Intangible resources	X_{10}-brand value	0.38	0.15
				X_{11}-local contractor	0.24	0.09

These two parts constitute the research sample of this study. Data of international sales, new contracts, international traffic market sales, and total revenue can be obtained directly from ENR. International revenue growth, new contracts growth, traffic market growth, and total revenue growth can be computed by comparing the operation for two consecutive years. In addition, the brand value is scored based on ENR ranking: the five points for the top 50 is four points for those ranked 51–100, three points for those ranked 101–150, two points for those ranked 151–200, and one point for those ranked 201–250. Moreover, the local contractor is a virtual variable.

Since the data units of each indicator are different and the numerical values vary greatly, data normalization is required before training the BPNN. This study uses the MATLAB mapminmax function to normalize the data. Data after normalization distribute in the interval [0, 1]. The normalized data multiplied by the weights of each index can be added to obtain the competitiveness index (CI). Taking the normalized sample data as the input of the BPNN and the competitiveness indices (CI) as the output of the BPNN, the BPNN following the inherent nonlinear regulation of the data can be trained.

The data preprocessing process of ENR 2016-2017 is consistent with ENR 2015-2016; due to the limited space, this study lists only part of the data preprocessing results of training set in ENR 2015-2016, as shown in Table 3.

3.4. Training for the BPNN. The algorithm process of BPNN training in this paper includes the following steps:

Step 1 (network initialization): determine the input based on sample input and output data series; the number of input nodes in the neural network is n, the number of hidden layer nodes is l; and the number of output nodes is m. The initial weight includes ω_{ij}, ω_{jk} and ω_{ij}, which are the weights corresponding to each node in the hidden layer and ω_{jk} is the weight corresponding to each node in the output layer. The threshold value includes a_j, b_k. η is the learning rate of the BP neural network. The sigmoid function [55] used as an excitation function in this study is presented as follows:

$$f(x) = \frac{1}{1 + e^{-x}}. \tag{1}$$

Step 2: the output of the hidden layer is as follows:

$$H_j = f\left(\sum_{j=1}^{n} \omega_{ij} x_i - a_j\right), \quad j = 1, 2, \ldots, l, i = 1, 2, \ldots, n. \tag{2}$$

Step 3: the output of the output layer is as follows:

$$O_k = \sum_{j=1}^{l} H_j \omega_{jk} - b_k, \quad k = 1, 2, \ldots, m. \tag{3}$$

Step 4: the performance error function in obtained as follows. Y_k indicates the target output:

$$e_k = Y_k - O_k. \tag{4}$$

Step 5: the adjustment algorithm for the weights:

$$\begin{aligned} \omega_{ij} &= \omega_{ij} + \eta H_j \left(1 - H_j\right) x_i \sum_{k=1}^{m} \omega_{jk} e_k, \\ \omega_{jk} &= \omega_{jk} + \eta H_j e_k. \end{aligned} \tag{5}$$

Step 6: the adjustment algorithm for the thresholds:

$$\begin{aligned} a_j &= a_j + \eta H_j \left(1 - H_j\right) \sum_{k=1}^{m} \omega_{jk} e_k, \\ b_k &= b_k + e_k. \end{aligned} \tag{6}$$

Step 7: it can achieve better result if iteration is stopped; otherwise, it is necessary go back to Step 2.

A BPNN comprises an input layer, hidden layer, and output layer [55]. The BPNN model built by the study consists of three layers of neurons, including a hidden layer, as shown in Figure 3.

The paper uses the MATLAB software to construct artificial neural network and achieve the BPNN algorithm. In the input layer of the neural network, there are 11 neurons corresponding to the 11 evaluation indices of the sample. In the hidden layer, there are 10 neurons. In the output layer, there is one neuron corresponding to the competitiveness evaluation index CI. The maximum number of iterations is set to 1000 times, training target accuracy is 0.0001, and the learning rate is 0.05. In the process of BPNN training, it is necessary to select test samples to test the training results. The test samples usually select about 10% of the total samples. Through the MATLAB stochastic process, 12 samples are selected as test samples and the other 111 samples are input into the neural network as training set. The neural network established after 6 iterations has reached the precision requirement and stopped training. After the network training is completed, 12 samples of the test samples are input into the BPNN to predict their CI and compared with the target output. Predicted results of the BPNN are shown in Figure 4. Error of the BPNN is as shown in Figure 5.

As can be seen from Figures 4 and 5, the output of the BPNN fits well with the target output. The maximum relative error is 0.0080 (Table 4). The maximum relative error is $0.0080 < 0.06$, which indicates that the model has a good generalization ability [56]. At the same time, it is proved that the established BPNN does not have the case of overfitting and has a good prediction ability, which can effectively reflect the implicit correlation and regulation contained in the training sample. The established BPNN can effectively evaluate the competitiveness of HSR construction contractors.

3.5. Results and Discussion on Competitiveness Evaluation of HSR Construction Contractors. By using MATLAB software and the established BPNN, the competitiveness of 133 transportation contractors in 2016-2017 is forecasted and evaluated, and the competitiveness of transportation contractors is analyzed from two aspects: national level and enterprise level. At the national level, the competitiveness of international transportation contractors is analyzed as a whole, and then the comparative analysis between Chinese and international transportation contractors is carried out to

Table 3: Normalized result of training data set.

Index number	X_1	X_2	X_3	X_4	X_5	X_6	X_7	X_8	X_9	X_{10}	X_{11}	CI
1	1.00	0.31	1.00	0.03	0.48	0.09	0.25	0.23	0.34	1.00	1.00	0.62
2	0.76	0.31	0.69	0.04	0.29	0.08	0.20	0.21	0.23	1.00	1.00	0.52
3	0.60	0.56	0.94	0.05	1.00	0.10	0.87	0.47	0.61	1.00	0.00	0.65
4	0.56	0.36	0.49	0.04	0.50	0.08	0.47	0.23	0.38	1.00	1.00	0.55
5	0.52	0.28	0.09	0.02	0.26	0.09	0.26	0.22	0.21	1.00	0.00	0.36
6	0.46	0.72	0.29	0.04	0.34	0.14	0.38	0.54	0.15	1.00	0.00	0.42
7	0.41	0.39	0.34	0.03	0.38	0.09	0.48	0.31	0.14	1.00	0.00	0.38
8	0.41	0.38	0.44	0.04	0.45	0.09	0.57	0.26	0.25	1.00	1.00	0.51
9	0.39	0.36	0.31	0.03	0.27	0.09	0.36	0.28	0.14	1.00	1.00	0.44
10	0.35	0.40	0.79	0.05	0.12	0.11	0.17	0.37	0.35	1.00	0.00	0.37
11	0.31	0.44	0.25	0.02	0.08	0.09	0.13	0.37	0.14	1.00	0.00	0.30
⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮
119	0.00	0.30	0.00	0.00	0.00	0.04	0.19	0.42	0.04	0.00	0.00	0.06
120	0.00	0.19	0.01	0.08	0.00	0.06	0.43	0.23	0.00	0.00	1.00	0.15
121	0.00	0.34	0.00	0.01	0.01	0.08	1.00	0.34	0.00	0.00	0.00	0.10
122	0.00	0.36	0.00	0.00	0.01	0.08	1.00	0.31	0.01	0.00	0.00	0.10
123	0.00	0.16	0.01	0.05	0.00	0.01	0.03	0.54	0.00	0.00	0.00	0.04

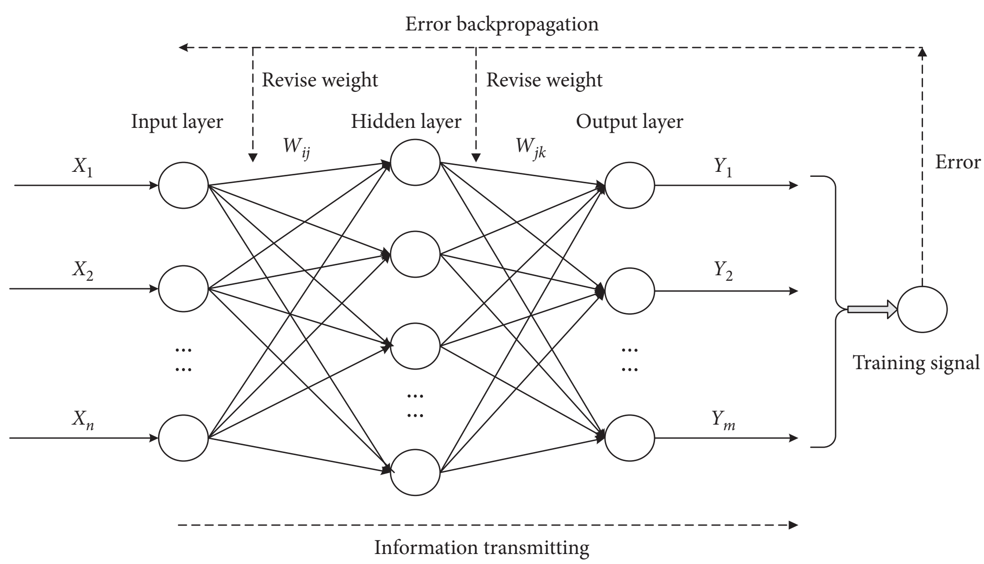

Figure 3: The BPNN model.

judge the position and competitive advantage of Chinese transportation contractors in the international arena. At the enterprise level, it mainly focuses on the analysis of Chinese transportation contractors to explore the European HSR market and conducts comparative analysis of the specific contractor in China and Europe, providing decision support for Chinese transportation contractors to explore the European HSR market.

ENR 250 had 133 transportation contractors in 2016-2017, of which 36 were Chinese transportation contractors. Due to the large gap between different contractors, the undifferentiated competitiveness evaluation of all contractors cannot accurately reflect the competitive advantage and competition gap of the contractors. Therefore, in order to analyze the competitiveness of transportation contractors more scientifically and reasonably, this study divided the transportation contractors into four levels, according to the evaluation results of competitiveness: market leader at the first level, market challenger at the second level, market chaser at the third level, and market follower at the fourth level [57].

The first level consists of contractors that have the strongest competitiveness and dominates the industry. According to clustering analysis, 21 contractors are regarded as the market leader: their competitiveness index range from 0.3 to 0.63 and the average competitiveness score was 0.43 points. The level of competitiveness of market leaders represents the highest level in the industry, and there is a large gap between contractors at other levels. The market leaders are large international contractors, covering a variety of different business areas, occupying the majority of the market. The competitiveness of the second level contractors is slightly weaker, and they are regarded as the market challenger: their competitiveness index ranges from 0.2 to

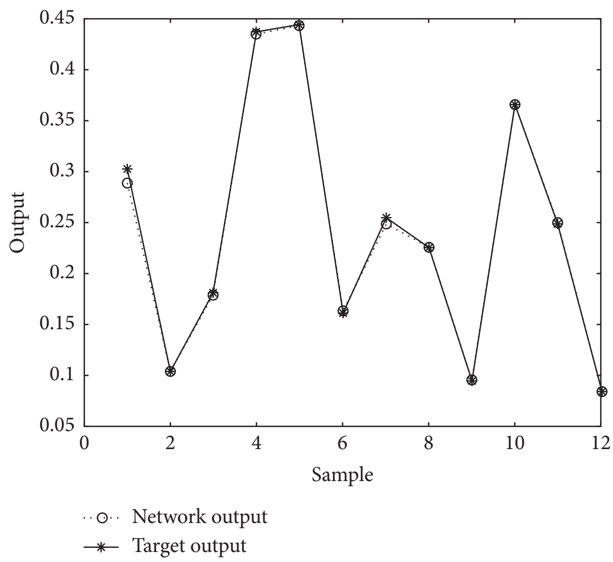

Figure 4: The BPNN output.

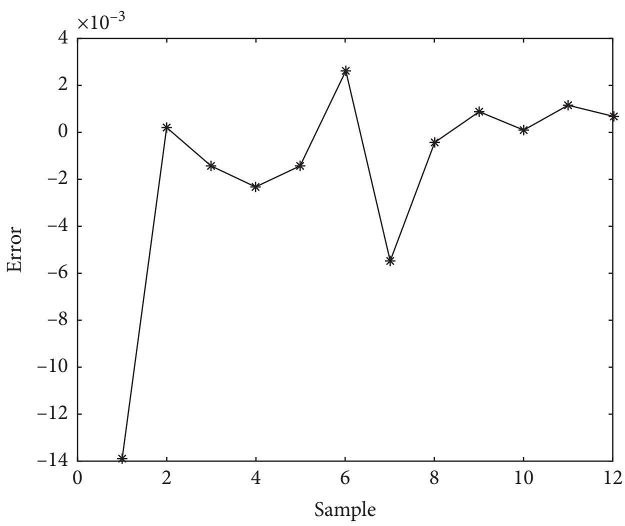

Figure 5: Error of the BPNN.

0.3, and the average competitiveness score was 0.25 points. A total of 39 contractors belong to the market challenger, which has strong competitiveness and has the opportunity to become a market leader. The third level consists of contractors that are part of the market chaser, who has a large growth space. Compared with participating in market competition, market chaser pays more attention to the growth and development of enterprises themselves, their competitiveness is not strong, and they belong to most groups in the market. A total of 54 contractors belong to the third level, the competitiveness index range from 0.1 to 0.2, and the average competitiveness score was 0.15. Market followers belong to relatively small-scale enterprises in the industry, or new enterprises, most of which are specialized business enterprises, which have a very large growth space, and the market competitiveness is weak at present. There are 19 contractors at fourth level, the competitiveness scores fall

Table 4: Error of the BPNN.

Number	Target output	Network output	Relative error
9	0.4437	0.4422	−0.0033
10	0.3651	0.3652	0.0003
12	0.24841	0.2496	0.0047
13	0.4363	0.4340	−0.0053
20	0.2541	0.2487	−0.0214
24	0.3025	0.2886	−0.0459
39	0.1807	0.1792	−0.0080
57	0.2259	0.2255	−0.0020
66	0.1615	0.1641	0.0161
95	0.1039	0.1041	0.0018
118	0.0841	0.0848	0.0080
122	0.0954	0.0963	0.0092

below 0.1, and the average competitiveness score was 0.08. It can be seen that there is a large competitiveness gap between contractors at different levels. In general, the competitiveness index of international transportation contractors presents a “diamond” distribution, the number of top (first level) and bottom (fourth level) contractors is small, and the number of middle level (second level and third level) contractors occupies the main body. The clustering analysis results is shown in Table 5.

This study focuses on the competitiveness of Chinese HSR construction contractors, so 36 Chinese contractors are stratified according to the same principles and compared with international contractors to analyze the status of Chinese contractors in the international arena. Among them, 5 Chinese transportation contractors are market leaders with the average competitiveness score of 0.46, including the China Communications Construction Group Ltd. (CCCG), China State Construction Engineering Corp. Ltd. (CSCEC), China Railway Construction Co. Ltd. (CRCC), China Railway Group Ltd. (CRG), and Power Construction Corp. of China (POWERCHINA), which is higher than the international average competitiveness level. It shows that China’s top transportation contractors have reached the international leading level and have strong competitiveness in the market; 2 Chinese contractors belong to the market challenger and the average competitiveness score was 0.24, which is slightly lower than the competitiveness of international contractors at the second level; 23 Chinese contractors are market chasers with the average competitiveness score of 0.15; 6 Chinese contractors are market followers with the average competitiveness score of 0.09. There is a big gap between the competitiveness level of the third- and fourth-level Chinese transportation contractors and the competitiveness level of international transportation contractors at the same level, and there is still room for improvement. On the whole, Chinese contractors have a certain competitiveness and market position in the international transportation construction market, and five contractors have already entered the international leading ranks. But, the competitiveness index of Chinese contractors is different from that of international contractors, and there is a big gap between different levels. Most of the contractors belong to market followers, and the number of market

Table 5: Clustering analysis of international HSR construction contractors' competitiveness.

Levels	Amount	Company	Competitiveness score	Mean score
Firs-level market leader	21	ACS, Actividades de Construcción y Servicios, Madrid, Spain China Communications Construction Group Ltd., Beijing, China VINCI, Rueil-Malmaison Cedex, France Hochtief AG, Essen, Germany China State Contruction Engineering Corp. Ltd., Beijing, China ……	>0.3	0.43
Second-level market challenger	39	Rizzani de Eccher, Pozzuolo del Friuli, Italy Acciona Infraestructuras SA, Madrid, Spain Sacyr, Madrid, Spain Società Italiana per Condotte D'acqua SPA, Rome, Italy Joannou & Paraskevaides Group, Guernsey, Channel Islands, U.K. ……	0.2~0.3	0.25
Third-level market chaser	54	Zhongmei Engineering Group Ltd., Nanchang, Jiangxi, China Contracting and Trading Co "C.A.T.", Beirut, Lebanon Takenaka Corp., Osaka, Japan Grupo Isolux Corsan SA, Madrid, Spain The Arab Contractors Co. (Osman Ahmed Osman), Cairo, Egypt ……	0.1~0.2	0.15
Fourth-level market follower	19	Beijing Urban Construction Group Co. Ltd., Beijing, China Combined Group Contracting Co. (KSC), Kuwait City, Kuwait Zhejiang Communications Constr. Group Co., Hangzhou, China Chongqing INT'L Construction Corp., Chongqing, China Ssangyong Engineering & Construction Co., Seoul, S. Korea ……	<0.1	0.08

challengers is relatively small. There is also a long way to go to develop into a leading international contractor, which is not conducive to the improvement of the overall competitiveness of China's transportation industry.

In addition, this study makes a detailed comparative analysis of the competitiveness of Chinese transportation contractors and international transportation contractors at different levels, and the static comparison chart is shown in Figure 6. The use of radar maps enables a systematic analysis of the competitiveness of HSR contractors, as well as a detailed comparative analysis of the competitiveness indicators from five aspects, including international ability, market expanding ability, transportation market ability, operation ability, tangible resources, and intangible resources. "INTL L_1" refers to the mean score of the first level of the international transportation contractors, and "CHA L_1" refers to the mean score of the first level of the Chinese transportation contractors. In addition, "L_2," "L_3," and "L_4" mean the mean score of the contractors at the second, third, and fourth levels, respectively.

From Figure 6, it can be seen that the competitive differences between Chinese contractors and international contractors are not the same at different levels, and contractors at different levels should adopt different competitive strategies by making accurate market positioning.

At the first level, the main competitiveness difference between Chinese transportation contractors and international transportation contractors lies in intangible resources and tangible resources, but there is no significant difference between the other indicators. In terms of intangible resources, the average score of international contractors is higher than 0.5, while the average score of Chinese contractors is less than 0.3, Chinese contractors lag behind international contractors. This is because Chinese transportation contractors have not entered the European market to contract projects, there is a gap in the European market, which is one of the important reasons why Chinese contractors needs to develop the European market. In terms of tangible resources, the Chinese contractor's score has been close to 0.3 and the international contractor is at about 0.1;

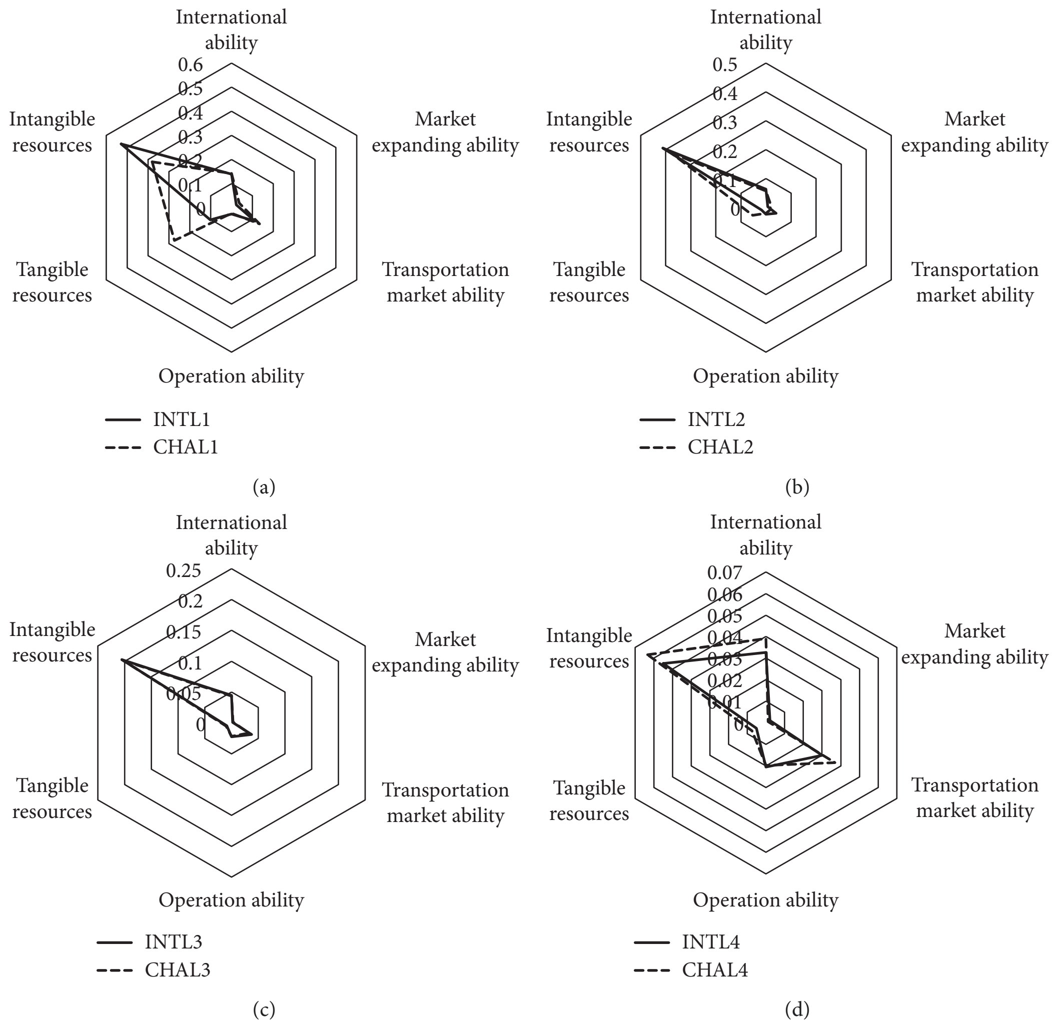

Figure 6: Comparisons between Chinese and international contractors.

Chinese contractors are ahead of international contractors. But at the same time, there is no difference in internationalization ability, which shows that China's domestic construction volume and construction demand are exuberant, providing huge orders for Chinese contractors, and the domestic market in China has laid a solid foundation for the development of Chinese transportation contractors. The first level of the comprehensive strength of Chinese transportation contractors has been equivalent to the international level; the future direction of development should focus on the development of overseas markets and enhance the brand value in the overseas market. Chinese contractors should rely on, but not over-rely on, the domestic market, actively take advantage of the profits made in the domestic market, and enter the construction markets of developed countries. The gap between international and domestic turnover should be reduced in order to grow into a leading international contractor.

The second level and the third level of Chinese transportation contractors compared with the international contractors in the transport market ability is slightly inadequate. In general, there is no significant difference in all aspects, and the competitiveness is basically equivalent to the same level of international contractors. But the second level of the number of Chinese contractors is too small, and there is still a lot of room for improvement. The competitiveness of Chinese transportation contractors at the third level should be greatly enhanced, so that more contractors can become market challengers, enhance the overall competitiveness of Chinese transportation contractors, and avoid the emergence of competitiveness gaps. Since the international traffic construction turnover accounts for the largest proportion of the international contractor's total turnover, the second and third level Chinese contractors should continuously strengthen their traffic construction ability and enhance international level if they want to obtain higher international market turnover. At the same time, it should not be satisfied with the position at the same level as the international level. It is necessary to continuously strengthen the improvement of various aspects and strive to enter the first level to achieve the goal of "Go globally" strategy for Chinese transportation contractors.

At the fourth level, the Chinese transportation contractor, as a market follower, has already outperformed the international contractor at the same level in all aspects, especially in terms of international ability, intangible resources, and transportation market ability; the average score is higher than the international contractor by nearly 0.01 points. Although Chinese contractors has a strong competitive advantage in the fourth level, but there is still a big gap compared with the other level of transportation contractors. It can be seen that the contractor at the fourth level is obviously weaker than the contractor at the other level in terms of tangible resources, which also shows that the contractor at the fourth level has a small market share. The market expanding ability is weak, so the contractors should actively participate in the market competition and open up the market, in order to seek the growth of the enterprise.

In general, the difference between the competitiveness of Chinese transportation contractors and international transportation contractors has become smaller and smaller, and Chinese contractors have been comparable to or even better than the international standards in the low level of competition. The probability that a large number of low- and medium-level Chinese transportation contractors will grow into top international contractors is increasing, and the number of Chinese contractors entering ENR 250 is also increasing year by year. Chinese transportation contractors have full potential in the international contracting market. However, contractors at all levels have the problems of poor operation ability and market expanding ability, which also shows that Chinese transportation contractors are still in an extensive development stage in overseas markets. There is still a long way to go for refinement and strategic development. Therefore, when Chinese transportation contractors enter the international market, they should pay attention to the choice of internal management and market development strategy and improve internal efficiency in order to obtain higher profits.

If China wants to build a Eurasian HSR and exploit the European HSR market, it will inevitably face direct competition from European local transportation contractors. Therefore, in view of the European HSR market, this study selects the top ranked enterprise in each level to analyze the competitiveness of European HSR construction contractors and Chinese HSR construction contractors. Since there are no contractors in Europe at the fourth level, only the first three levels are analyzed. In the first level, the European representative contractor is ACS and the Chinese contractor is China Communications Construction Group Ltd. In the second level, the European contractor is Rizzani de Eccher and the Chinese contractor is China Metallurgical Group Corp. In the third level, the European contractor is Grupo Isolux Corsan Sa and the Chinese contractor is Zhongmei Engineering Group Ltd. The static comparison chart between Chinese HSR construction contractors and European HSR construction contractors is shown in Figure 7. At the enterprise level, through comparative analysis, it can be seen that the competitiveness gap between different levels contractors and between Chinese contractors and European contractors is obvious. The strongest competitor to Chinese contractors entering the European HSR market is Spanish ACS. ACS ranks first among 133 international transportation contractors worldwide, followed by China Communications Construction Group Ltd., ranking second, with a 1% difference in competitiveness index score. From the detailed analysis of each index, the competitive advantage of China Communications Construction Group Ltd. lies in the strong traffic market ability and tangible resources, but in intangible resources, internationalization ability is lower than ACS. The intangible resources of ACS are twice as high as China Communications Construction Group Ltd. and have strong market recognition and local advantages in the European HSR market. Therefore, China Communications Construction Group Ltd. should give full play to its professional ability in traffic construction, enhance its brand value in overseas markets, continuously develop new international markets, and enhance its share of international markets.

In the second level, the European contractor is Rizzani de Eccher and the Chinese contractor is China Metallurgical Group Corp. (MCC), ranked 37 and 22 among international transportation contractors but 48 and 89 in the ENR 250 rankings, respectively. The main reason is that the traffic market ability of MCC is lower than that of Rizzani de Eccher and the transportation sector is not a dominant area of MCC. In addition, MCC also has shortcomings in market expanding ability, resulting in a 19% difference in overall competitiveness scores. MCC's advantage lies in its tangible resources, with a score of 0.1. Therefore, if MCC wants to enhance its international competitiveness and develop the transportation market, it should adopt a diversified development strategy.

The third level of Zhongmei Engineering Group Ltd.'s competitiveness is slightly higher than Grupo Isolux Corsan Sa, but there is no obvious gap. Zhongmei Engineering Group Ltd. is superior to Grupo Isolux Corsan Sa in terms of internationalization ability and operation ability, of which the international capability is higher than Grupo Isolux Corsan Sa by 0.1. Grupo Isolux Corsan Sa relies on the advantages of local enterprises, so that the competitiveness is not significantly behind. From this, it can seem that intangible resources play a very important role in the competitiveness of enterprises. Therefore, if Chinese HSR construction contractors want to develop the European HSR market, they must focus on raising brand value and overseas visibility to enhance the intangible resources of enterprises.

In summary, the competitiveness of top transportation contractors in China is comparable to that in Europe, and there is no significant difference. The Chinese contractors at the second and third levels are not specialized transportation enterprises, and the transportation construction is not the advantage area, so their competitiveness is also slightly lower than the European contractors at the same level. Therefore, in order to improve the strength and international influence of Chinese contractors in the field of international transportation engineering contracting, it is necessary to cultivate a group of specialized transportation enterprises, actively explore the international market, and increase their share in the international transportation market. At the same time, contractors in other fields are encouraged to adopt diversification strategy while maintaining their own development advantages to meet the huge domestic and international transport infrastructure construction needs. Most of the European transportation contractors are

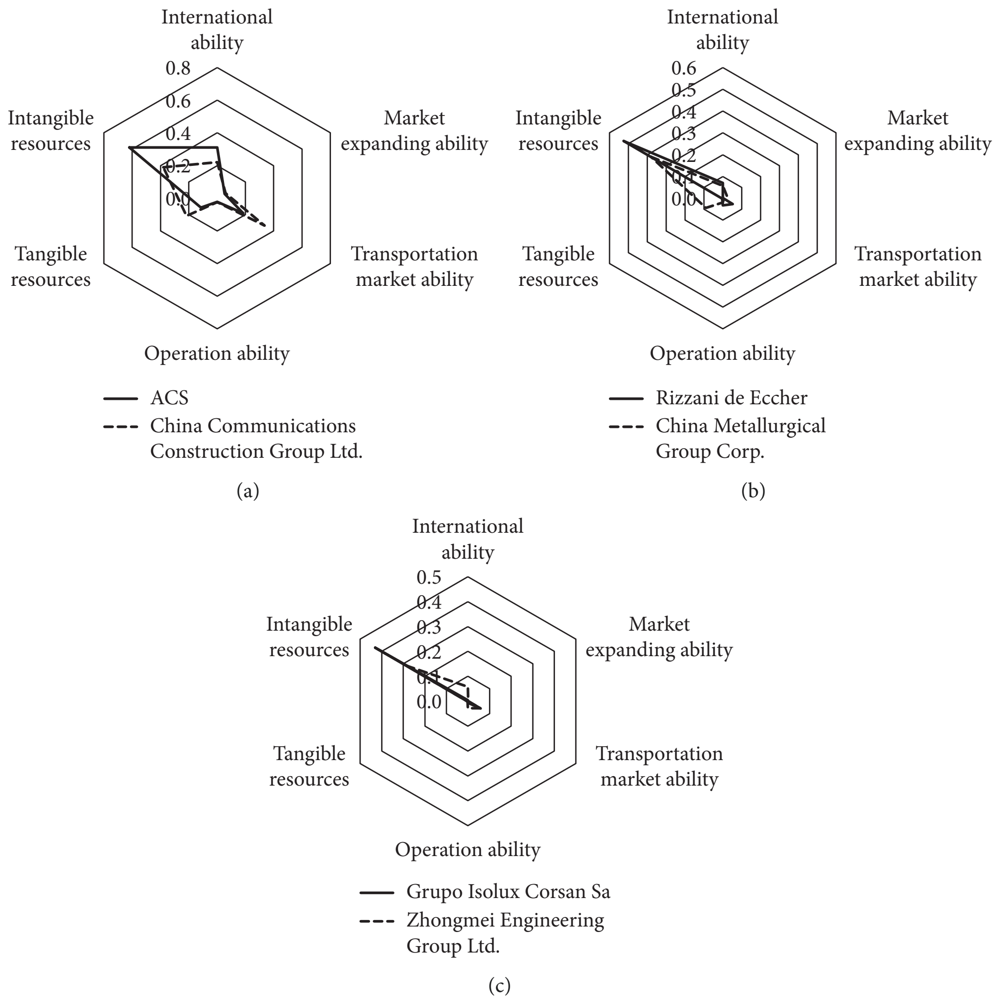

Figure 7: Comparisons between Chinese and European contractors.

concentrated on the middle and high levels, while most of the Chinese transportation contractors are concentrated in the middle and low levels. On the whole, there is still a big gap and great room for improvement between the Chinese contractors and the European contractors. Chinese transportation contractors should pay attention to enhancing the operation ability, internationalization ability, and market expanding ability of enterprises and enhance the competitiveness of enterprises in all aspects. Finally, it can be seen that there is a big gap between Chinese transportation contractors and European transportation contractors in terms of intangible resources, mainly because the European market is a blank area for Chinese contractors and there is no Chinese transportation contractors to undertake projects in Europe. Therefore, it is of great significance for Chinese transportation contractors to develop the European HSR market to fill the gap in the market, to obtain the European market projects, and to increase the international turnover; and also, the European market is a representative of the developed markets. It is an opportunity to enter the European market to open up the HSR contracting market in developed countries, compete with international top contractors, and accelerate the internationalization process of Chinese transportation contractors. It also laid a good foundation for the realization of the four cross-border HSR lines plans of “One Belt and One Road” initiative.

4. Grey-BPNN Model Construction for Competitiveness Evaluation of Rail Equipment Suppliers

Rail equipment suppliers are the technical core of HSR industry chain, and the competitiveness of rail equipment suppliers plays an important role in contracting HSR project. The core technology is difficult and innovative, with only about 10 suppliers around the world mastering the technology. It can be seen that the number of HSR contractors in the world is small and information acquisition is difficult. Based on the principles of availability, reliability, and authenticity of sample data, this paper selects 7 large-scale listed companies such as China Railway Rolling stock Corporation (CRRC), Bombardier, Alstom, Finmeccanica, Siemens, Kawasaki, and Hyundai as research samples.

Based on the characteristics of grey relational analysis and BPNN, this study constructs the Grey-BPNN model for the competitiveness evaluation of rail equipment suppliers. The Grey-BPNN model construction process is shown in Figure 8. In the first stage, the competition of the HSR contractor is evaluated by grey method: firstly, according to the literature review and the characteristics of rail equipment suppliers, the competitiveness evaluation index system is constructed; then, the grey relational analysis is used to analyze the samples, and the grey relational degree of each rail equipment suppliers is obtained. The competitiveness of the rail equipment suppliers is preliminarily evaluated by grey method, and the processed samples are divided into training set and test set. In the second stage, the BPNN is trained to construct a complete Grey-BPNN model, and the validity of the model is tested: firstly, the competitiveness indices is used as the input unit of the BPNN, the grey relational degree is used as the target output unit, and the training set is brought into the BPNN model for training; then, the test set is used for error testing, and the model is modified according to the result of the test. Finally, the BPNN with grey property is obtained, and the construction of Grey-BPNN combinatorial model is completed. The Grey-BPNN model is constructed to evaluate the competitiveness of rail equipment suppliers, which provides objective and scientific decision support and strategic basis for Chinese contractors to exploit the European HSR market, in order to enhance the competitiveness and reputation of Chinese contractors in the international market.

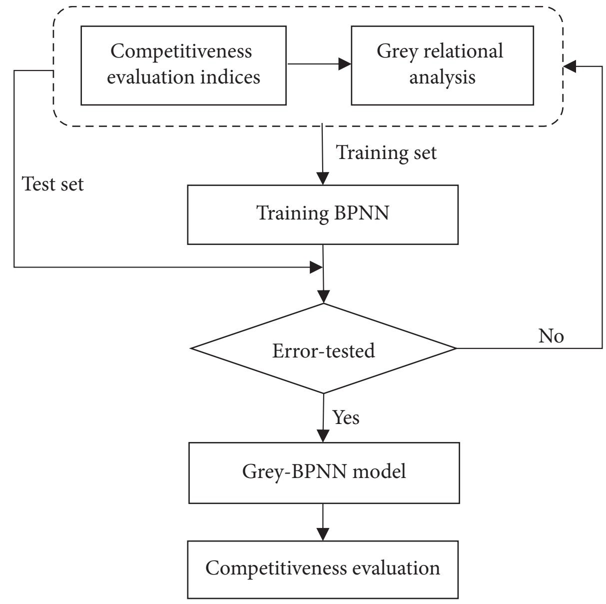

FIGURE 8: Grey-BPNN model construction process.

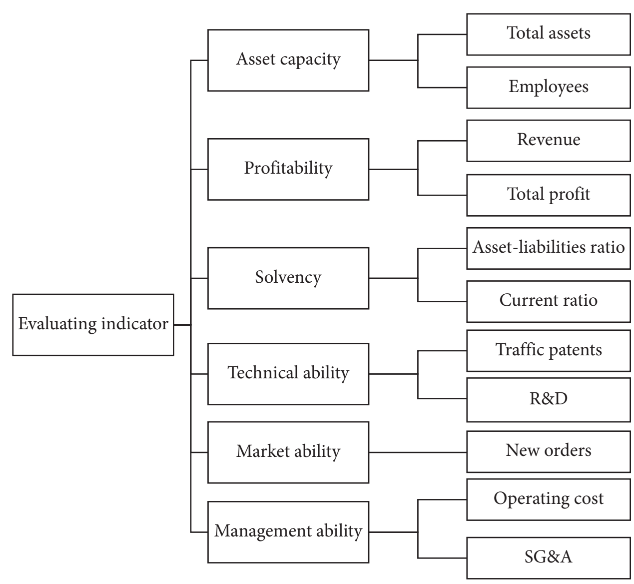

FIGURE 9: Evaluation system of rail equipment suppliers' competitiveness.

4.1. Competitiveness Evaluation Indices System for Rail Equipment Suppliers. With China, Japan, France, Germany, and some others as the major countries owning the core HSR construction technologies, companies in these countries, such as CRCC of China, Kawasaki of Japan, Alstom of France, Siemens of Germany, and other seven enterprises of other countries, are the main providers of equipment-manufacturing technologies. Their status as suppliers of HSR equipment has been widely recognized by the industry and academia [6]. Since this study uses the annual financial statements of 7 rail equipment suppliers in 2016 and the DII database as the data source, financial indicators and non-financial indicators are selected to construct the competitiveness evaluation system for rail equipment suppliers. In order to ensure the applicability and comprehensiveness of the competitiveness evaluation system, this study mainly divides into two steps to select competitiveness indicators: the first step is to select comparable competitiveness indicators in the field of HSR equipment according to the competitiveness theory and existing research literature; the second step is to analyze the operation of the company in detail with the company's annual financial statements and the database, eliminates the indicators with low correlation with competitiveness, retains the important indicators, and classifies and integrates them to construct the competitiveness system of rail equipment suppliers. Considering the availability and reliability of data, this study selects 11 indicators from 6 aspects: asset capacity, profitability, solvency, technical ability, market ability, and management ability. The evaluation system of rail equipment supplier's competitiveness is as shown in Figure 9. The first kind of assets capability, enterprise assets, is the fundamental source of enterprise competitiveness, including human, financial, and material, especially for HSR contractors; enterprise assets are the basis for product production, and product innovation is indicated by the total assets and employees [58]. Profitability of the enterprise, to a large extent, reflects the competitiveness of the enterprise and indicates the position of enterprises in the market and the potential of future development, so it is indicated by the revenue and total profit [58, 59]. Solvency is the key factor to determine the competitiveness of listed companies, which can effectively reflect the rationality of enterprise asset structure and risk control ability and is indicated by the asset-liabilities ratio and current ratio [60]. Technology is the core competence of rail equipment suppliers. With advanced production technology and R&D capabilities, the competitiveness of suppliers can be fundamentally enhanced. Technical ability is indicated by the traffic patents and R&D. Market ability, similar to the new contracts in the competitiveness index of high-speed construction contractors, reflects the future development potential of enterprises and is indicated by the new orders. Management ability refers to the operation ability of enterprise assets, which can help to explore the potential benefits from the internal environment of the enterprise and enhance the utilization ability of assets in order to obtain the sustainable competitive advantage, and is indicated by the operating cost and SG&A [61].

4.2. Grey Relational Analysis of Rail Equipment Suppliers. In order to ensure the availability and reliability of the data, this study uses the annual financial statements of 7 rail equipment suppliers in 2016 and the DII database as the data source. The Finmeccanica is the second largest industrial high-tech group in Italy. Its business covers defense, aviation, automation control, transportation, and energy. It operates in more than 100 countries and has subsidiaries specializing in rail transit. Bombardier is a multinational manufacturer of transportation equipment in Canada with strong capabilities in rail transit. Hyundai Rotem is a subsidiary of Hyundai Motor Group. The Hong Kong Railway, Taiwan Railway, India New Delhi Metro, Vancouver train, and Canada and Kazakhstan Almaty subway all use Hyundai Rotem. Kawasaki is one of the important members of Japan's military industry, covering rail transit, aviation, internal combustion engine, machinery, shipping, and other departments. Alstom is a global provider of industrial equipment, generators, rail transit infrastructure, etc. Siemens is a leading enterprise in the field of electronic and electrical engineering in the world. It has strong technical capability and rich experience in rail transit. In 2018, Siemens officially released the new high-speed train "VelaroNovo," which has a breakthrough advantage in the manufacturing of HSR equipment. China South Railway (CSR) and China CNR Corporation Limited merged into CRRC Corporation Limited on December 30, 2014, becoming one of the world's largest rail transit equipment manufacturers and solution providers. All seven large companies have the technology and capability to build and develop HSR and are world's leading suppliers of high-speed equipment. The data of rail equipment suppliers are as shown in Table 6.

Grey relational analysis is generally applicable to situations where the meaning and dimensions of the sample are identical. In order to eliminate the influence of dimensionality on data analysis, the data are processed to mean value to meet the requirements of grey relational analysis. According to the principle of selecting the maximum value for the index with positive influence on competitiveness and the minimum value for the index with negative influence, the reference sequence $K = (3.4836, 2.9533, 3.4908, 3.6758, 4.6849, 0.7921, 1.3434, 0.2414, 4.8720, 3.4228, \text{and } 0.0222)$. The meaning of the reference sequence refers to the optimal state of competitiveness that can be achieved in the context of seven HSR contractors. Then, according to the formula of Deng's correlation degree, the grey relational degree is calculated [33]. The results are shown in Table 7.

Through the grey correlation analysis, the following conclusions can be drawn.

First, Siemens ranked first with a grey relational degree of 0.9952, indicating that Siemens is the most competitive among rail equipment suppliers. At the same time, Siemens is also one of the rail equipment suppliers in Europe. It has a good corporate reputation and a wide range of business partnerships with local advantages. Siemens is far ahead in R&D investment, with strong research and manufacturing capabilities for HSR equipment. The newly developed high-speed train "VelaroNovo" has greatly improved in terms of cost, design, and intelligence, etc., which is an important embodiment of its technical ability. Therefore, Siemens is the strongest competitor for Chinese HSR suppliers to enter the European market.

Second, CRRC competitiveness ranks third, and it has already ranked among the top suppliers in the field of HSR equipment manufacturing, but there is also a lot of room for development. Among the 11 indicators, CRRC and Siemens have the largest gap between the traffic patents and R&D, indicating that CRRC needs to enhance the technical investment and technical ability of enterprise. At the same time, it also reflects the lack of patent consciousness and the insufficient attention to innovation research. When contractors exploits overseas markets, lack of patent consciousness is likely to bring intellectual property litigation to enterprises, thus bringing a series of risks to the project. Faced with strict technical standards in the European HSR market, Chinese contractors may face technical barriers due to insufficient technical ability and increase the difficulty of opening up the European HSR market. The main advantage of CRCC lies in the new orders, which may be due to the large number of orders brought to Chinese contractors by the implementation of the "One Belt and One Road" initiative and the rapid construction process of HSR in China. It shows that CRCC has a strong competitive ability in sustainable development, should seize the development opportunities, open up overseas markets, and strive to expand its market share.

Third, there is a big gap between the competitiveness of the rail equipment suppliers, and there is a 32% difference in grey relational between Hyundai and Siemens. Due to the small number of market competitors, the lack of market competition, and the large gap between the competition strength of different competitors, it is easy to form an oligopolistic market situation. Therefore, rail equipment suppliers should constantly improve the competitiveness of enterprises so as not to be squeezed out of the market.

4.3. Construction and Evaluation of the Grey-BPNN Model. The grey relational degree is used as the output of the BPNN, and the 11 indices of rail equipment suppliers are used as

Table 6: Data of rail equipment suppliers.

Rail equipment suppliers	CRRC	Bombardier	Alstom	Finmeccanica	Siemens	Kawasaki	Hyundai
Total assets[a]	51,027	22,826	16,946	29,954	148,346	14,680	14,307
Employees[b]	183,061	66,000	32,800	45,631	351,000	35,127	118,320
Revenue[a]	34,649	16,339	8,621	14,162	93,980	13,214	7,492
Total profit[a]	2,554	427	422	1,159	6,589	812	585
Asset-liabilities ratio[c]	63.41	100.00	74.10	82.77	72.31	74.09	59.55
Current ratio[c]	1.25	1.14	1.06	0.97	1.29	1.28	1.66
Traffic patents[d]	1,269	202	884	15	13,345	2,690	37,245
R&D[a]	1,461	287	207	1,620	5,584	380	1,882
New orders[a]	396,078	15,400	11,854	23,542	102,046	11,734	8,419
Operating cost[a]	27,446	14,622	6,861	12,267	65,875	11,126	60,768
SG&A[a]	4,386	1,133	636	861	13,769	98	9,997

Note. [a]Million dollars, [b]person, [c]percent (%), [d]item.

Table 7: The result of equalization and grey relational analysis.

Rail equipment suppliers	Total assets	Employees	Revenue	Total profit	Asset-liabilities ratio	Current ratio	Traffic patents	R&D	New orders	Operating cost	SG&A	Grey relational degree
CRRC	1.1983	1.5403	1.2870	1.4250	0.8435	1.0116	0.1596	0.8954	4.8720	0.9656	0.9942	0.9136
Bombardier	0.5360	0.5553	0.6069	0.2382	1.3302	0.9225	0.0254	0.1759	0.1894	0.5144	0.2568	0.8930
Alstom	0.3979	0.2760	0.3202	0.2357	0.9857	0.8578	0.1112	0.1266	0.1458	0.2414	0.1442	0.8984
Finmeccanica	0.7034	0.3839	0.5260	0.6464	1.1010	0.7850	0.0019	0.9931	0.2896	0.4316	0.1953	0.9200
Siemens	3.4836	2.9533	3.4908	3.6758	0.9619	1.0439	1.6786	3.4228	1.2552	2.3176	3.1213	0.9552
Kawasaki	0.3447	0.2956	0.4908	0.4528	0.9856	1.0358	0.3384	0.2327	0.1443	0.3915	0.0222	0.9017
Hyundai	0.3360	0.9956	0.2783	0.3261	0.7921	1.3434	4.6849	1.1535	0.1036	2.1379	2.2661	0.7255

input. Using MATLAB to build the BPNN with 12 neurons of hidden layer, the maximum number of iterations is set to 500 times, training target accuracy is 0.0001, and the learning rate is 0.05. Because the network output is grey, this study is called Grey-BPNN model. The output of Grey-BPNN model is as shown in Figure 10. The error of Grey-BPNN model is as shown in Figure 11.

Since the increment of the vertical axis in Figure 7 is 0.01, it is apparent from the graph that there is a big gap between the network output and the target output. In fact, the maximum gap is within 0.03, indicating that the model is highly fitted. The detailed error values are shown in Table 8. The maximum absolute error is $0.0336 < 0.06$, which indicates that the model has good generalization ability [56]. It can be considered that this model has effectively grasped the nonlinear regulation contained in training samples and can play a good role in competitiveness evaluation.

In summary, the Grey-BPNN model established by the combination of grey relational analysis and BPNN is an optimization improvement of the BP model, which can well handle the prediction and evaluation of small samples. Grey-BPNN model can combine the advantage of grey relational analysis in dealing with small sample problem, and it also has the function of the BPNN autonomous learning optimization and can be applied to predict the competitiveness of rail equipment suppliers. It provides new ideas and methods for competitiveness evaluation and prediction.

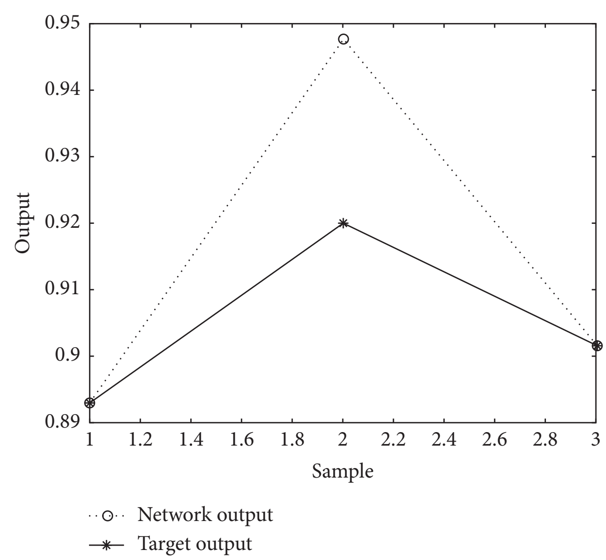

Figure 10: Grey-BPNN model output.

5. Conclusions

This study researches the competitiveness of Chinese HSR construction contractors and rail equipment suppliers in the European HSR market using the proposed Grey-BPNN model that combines grey relational analysis and BPNN and provides improvement suggestions for these Chinese contractors and suppliers.

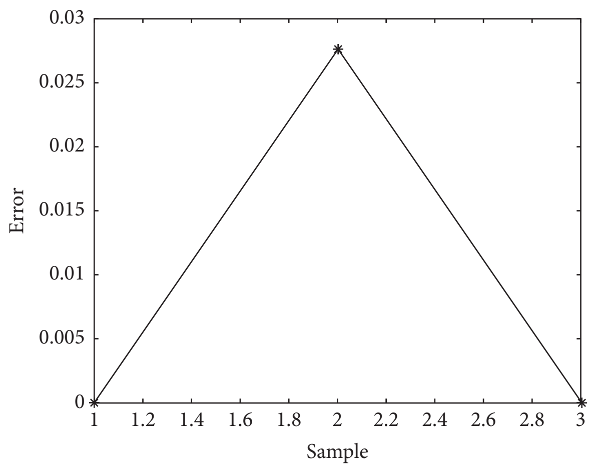

Figure 11: Error of Grey-BPNN model.

Table 8: Error of the Grey-BPNN model.

Rail equipment suppliers	Target output	Network output	Relative error
CRRC	0.9136	0.9136	0.0000
Bombardier	0.8930	0.8930	0.0000
Alstom	0.8984	0.9286	0.0336
Finmeccanica	0.9200	0.9476	0.0300
Siemens	0.9552	0.9552	0.0000
Kawasaki	0.9017	0.9017	0.0000
Hyundai	0.7255	0.7255	0.0000

In the field of HSR construction, the differences of competitiveness between Chinese contractors and international contractors are getting smaller. The number of Chinese contractors listed in ENR 250 is also increasing year by year, demonstrating the great potential of Chinese contractors in the international construction arena. Due to the lack of experience of Chinese contractors in HSR construction in developed countries and the lack of recognition in the high-end international construction market, Chinese contractors are lagging behind in overall competitiveness in the exploration of the European HSR market. Chinese contractors at all levels have similar problems of poor market expanding ability and high reliance on the domestic market, which shows that Chinese contractors are currently at a stage of extensively developing overseas markets and there is still a long way to go. To increase profits in the long run, Chinese contractors should not over-rely on the domestic market and should actively open up the international market, strengthen internal management and market development strategies, and improve the internal efficiency.

For the rail equipment suppliers, comparing to Siemens, HSRCRRC is inferior in almost all aspects and really needs to leverage on its extensive HSR experience in China and the “Belt and Road Initiative” by the Chinese government to attract business in the European HSR market. Chinese HSR contractors have strong sustainable development capabilities, mainly driven by the large domestic demand for HSR and the overseas HSR contracts brought by the “Belt and Road Initiative”. CRRC should seize development opportunities and take the domestic market as a support to actively expand its overseas HSR market. Compared to their international competitors, Chinese rail equipment suppliers did not invest enough in research and development (R&D) and the acquisition of patents. It can be foreseen that the various technical standards, specifications, and intellectual property requirements will become the European market entry barriers for Chinese rail equipment suppliers. Therefore, it is crucial for Chinese rail equipment suppliers to strengthen R&D and increase patents for future competition.

This paper contributes to literature by proposing a Grey-BPNN model that combines the grey relational analysis and BPNN, and is expected to analyze the overall competitiveness of Chinese contractors in the European HSR market. This study also contributes to HSR construction practices by providing informative decision support for evaluating the competitiveness of Chinese contractors in the HSR market in Europe.

Some limitations of this study would require future research. First, survey data were not taken into account on subjective factors, such as relational capital, organizational learning, and cross-cultural ability. Thus, there were no purely qualitative variables within the analysis of the factors. Future research can include qualitative evaluations of influencing factors to strengthen the evaluation and prediction. Second, the GREY-BP model constructed in this study has been proved to be effective in competitiveness evaluation. The application scope of the model can be further explored, such as bidding decision-making and partner selection [62], in future investigation.

Data Availability

The data used to support the findings of this study are available from the corresponding author upon request.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

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